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Biofilms in Dental-Unit Waterlines

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Biofilms are well-organized communities of cooperating microorganisms that can include bacteria, protozoa, diatoms, and fungi. Their presence in dental-unit waterlines has been known since 1963 (1-7). The discovery that biofilms contribute to the microbial contamination of dental-unit waterlines has made the need for cleansing systems apparent, to minimize the potential danger of infection and cross contamination (8, 9).

Biofilms predictably form in both natural and artificial environments where surfaces are bathed with an aqueous source of organisms and nutrients. In dental-unit waterlines, biofilms have been measured to be 30-to-50 micrometers thick (10). Layers upon layers of organisms form intricate structures, including nutrient channels, utilizing polysaccharide adherence and matrix compounds, yielding biofilms that are mechanically tenacious and resistant to chemical attack. Various potential pathogens, both environmental and human-derived, have consistently been cultured from dental units worldwide (11).

While serious infections have only rarely been attributed to dental waterlines, it is clear that dental patient exposure to known water-born pathogens is common and that further epidemiological research is warranted. Of particular concern are those patients whose immune systems have been compromised by disease or age. Even lacking strong evidence of adverse health effects, the professional and ethical considerations alike, argue that reasonable steps should be taken to improve the quality of dental water. The American Dental Association's goal is to reduce microbial counts to below 200 colony-forming units (CFU) per ml in the unfiltered output from dental-water supply lines (12,13).

Microbial populations of the biofilms found in dental-unit waterlines include the most common opportunistic pathogens linked to hospital-related waterborne infections; *e.g*., *Pseudomonas*, *Legionella*, and non-tuberculous *Mycobacterium* (12). Predominant early colonizers include *Pseudomonas* spp., *Pasteurella*, *Moraxella*, *Ochrobactrum*, with *Aeromonas* spp., *Flavobacterium*, and *Acinetobacter* spp. being observed later. Many of these organisms are opportunistic pathogens (14). Oral flora, most likely deriving from "suck-back" events, are also commonly reported; *e.g*., *Lactobacillus*, *Streptococcus*, *Bacteroides*, *Veillonella*, and *Candida* (12). While both the American Dental Association and the Centers for Disease Control and Prevention endorse flushing water lines for several minutes prior to the first patient visit and for 20 to 30 seconds between patients, this infection control effect is transient (13). Flushing between patients will most likely reduce levels of oral flora, which do not typically colonize upstream tubing, but most species rapidly return to pre-flush levels as pieces of biofilm are dislodged. Additionally, at room temperature, the concentration of aqueous bacteria can double every twenty minutes.

The quality of dental-unit water is of considerable importance since patients and dental staff are regularly exposed to water and aerosols generated from the dental-unit (15). The inspiration of contaminated aerosols and direct exposure of open wounds is probably of most concern. Average living microbial counts in water from handpieces and air-water syringes are in the range of 300,000 to 400,000 CFU per ml and can easily contain millions of CFUs per ml of water (16). This means that patients are exposed to water of lower quality with respect to microbial content, than untreated water from major rivers in the United States (e.g., Chicago, Ohio, and Rio Grande that are reported to contain an average of 235,000 CFU per ml (17).

High microbial counts in dental waterlines do not reflect a lack of quality in city water as delivered to the office, which is usually well below 500 CFU per ml. Several features of dental-unit waterlines are responsible for this situation, including surface area, surface chemistry, and flow rates. Most plastic dental tubing has an inside diameter of 1/16-to-1/8 inch (13), and thus has a very large surface area to volume ratio. The hydrophobic surface of waterline plastics promotes the attachment and colonization of biofilm organisms. At peak usage, the flow rate in a dental handpiece can be between 2-to-10 ml per minute. In contrast, most household water pipes are made of 1/2-inch diameter copper with flow rates of about 5-liters per minute. This is approximately 1,000 times greater than the flow through dental-unit waterlines. The water in the dental lines is also completely stagnant on weekends and evenings. The layered structure of biofilms (limiting diffusion) combined with the low flow conditions renders these microbial colonies intrinsically resistant to many biocides and cleansing schemes. Active biofilms then become the primary reservoir for continued contamination of the system.

Improving the microbial quality of dental-unit water, as means become available, is a natural part of maintaining a high quality of patient care and staff protection. It takes less than five days before initial microbial counts reach a plateau of 200,000 CFU per ml in newly installed waterlines. Various biofilm maturation processes (such as bacterial encapsulation) that continue for up to 120-days can increase disinfection resistance as the biofilm ages.

Schemes to reduce microbial counts in dental-treatment water fall into four broad categories: (i) use of water systems that are independent of public systems, including those designed to deliver sterile water; (ii) chemical treatments that are provided either continuously or intermittently; (iii) filters placed inline just before the point of use (*i.e.* handpiece, three-way syringe, ultrasonic scaler); and, (iv) devices to create turbulent and/or high energy flow conditions to cleanse fine tubing (13). An in-depth discussion of the first three of these schemes, along with a list of twenty six products cleared by the U.S. Food and Drug Administration, was recently published by the Council on Scientific Affairs of the American Dental Association (13). In general, however, no perfect product or approach has yet been universally recognized.

Independent water systems provide the opportunity to introduce chemical agents, but must be carefully maintained and monitored. Independent systems can easily become contaminated from a variety of sources. While systems designed to deliver sterile water can be kept free of microorganisms, they usually deliver water only through dedicated accessories and can be quite expensive. Many chemical agents have been studied and some (including iodine, ozone, stabilized hydrogen peroxide compounds, and silver) can apparently reduce microbial contamination in waterlines. Several recent studies have demonstrated that dental-unit waterline contamination can be controlled when dental personnel use available technologies and adhere to recommended maintenance protocols (18-21). Clinicians should consult with the manufacturer of their dental-unit prior to introducing any chemical agents.

There is a need for more information regarding the interaction of biocides and disinfectant byproducts with oral and dental tissues. For example, some chemical agents have been reported to decrease the adhesion of resins to both enamel and dentin (22). Point-of-use filters can be quite effective and simple to install. However, (i) filters do not address the central issue of a large retained biomass within the dental unit, (ii) many filters will not remove bacterial endotoxins, and (iii) filter systems can be high-maintenance in terms of both time and cost (13). Devices that create transient high energy cleansing conditions in water lines are under development (personal communication, Colonel Shannon Mills, DC, USAF).

Monitoring protocols are an inherent part of any dental waterline treatment program to ensure that it is meeting expectations. This is quite analogous to the use of spore tests or color indicators to monitor the effectiveness of steam autoclaves. Commercial water-testing laboratories can enumerate microbial counts and water-testing kits are available for in-office use (23). Expert consensus appears to indicate that there is little need to evaluate water quality prior to implementing a treatment program nor is there a need to identify specific organisms (13). Data from the analysis of thousands of dental offices leaves little hope that this is not a universal problem. Information regarding specific organisms is highly useful in only a few circumstances, such as where a waterline is refractory towards treatment or a waterborne illness is suspected (13).

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